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Remarks and hypothesis concerning the stereoscopic examination of mud and lime plasters in Minoan Architecture: case studies for Monastiraki and Knossos

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This contribution discusses the recent data from the Monastiraki and Knossos-Anetaki excavations on the use of mud and lime plaster during the Minoan period. The primary goal is to analyse building materials as part of material culture, with a clear emphasis on understanding ancient technology. Likewise, this research aims also to shed light on technological aspects related to the built environment, such as the presence of specialized roles in the architectural *chaîne opératoire* and the combined used of different types of plasters. The research questions concentrate on investigating diverse plaster materials, specifically lime and mud plaster, excavated in two Minoan centres, and discussing their properties, typology, and lastly the impact of fire on their preservation.

1. Background

The interaction of lime and mud plaster with the effects of fire on earthen building materials is rarely discussed in the archaeological record; this investigation attempts to fill this gap by presenting recent data from the site of Monastiraki, a Minoan site located in the Amari valley and occupied during the Protopalatial period, and Knossos, doubtless the most well-known Minoan centre in Crete, which was occupied from the Neolithic to the Roman period. The material discussed was excavated under two projects directed by Dr. Athanasia Kanta: the first project, Monastiraki, has been excavated since the 1980s, whereas the Knossos excavation, also known as the Knossos-Anetaki project, was undertaken during 2013-2017 and documents materials from

Minoan, Mycenaean, and Roman contexts (Kanta and Marazzi 2006; Kanta and Marazzi 2014) (Figs. 1 and 2).

The analysis of the same type of building materials from two diverse Minoan sites from different regions of the island offers a clear opportunity to develop a more inclusive dataset, and increases the amount of reliable information that has been systematically investigated and examined. The combined perspective from the two sites is extremely relevant to understand Minoan plaster production and usage from different contexts, as Knossos presents materials from an urban centralised town, while Monastiarki from an inland country centre.

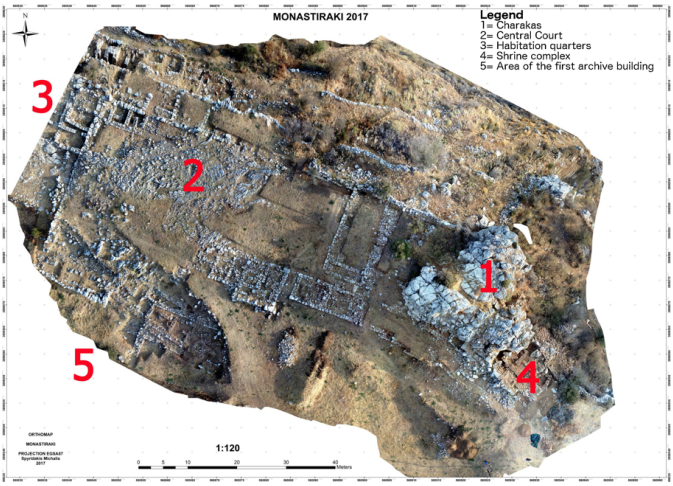

Figure 1. Color

The use of lime and mud plaster in Minoan construction is a well-documented phenomenon in both excavation reports and scholarly literature (Brysbaert 2008; Cameron 1972; Cameron, Jones and Philippakis 1977; Heaton 1911; Jones 2005). Lime plaster in particular has been extensively studied in order to determine its composition, technology, and functionality. For example, lime plaster has been recorded from a variety of contexts including wall finishes, paving, and furniture creation (Shaw 2009, 141-156; Wright 2005, 143-178). The first study on lime technology by Heaton (1911, 697-710) dates back to the earliest excavations at Knossos, and was conducted in the early 20th century. Since then, numerous researchers have contributed geoarchaeological and micromorphological perspectives to the discussion on lime technology in Greece (Boness, Panagiotopoulos and Goren 2017; Budak, Maravelaki-Kalaitzaki and Kallithrakas-Kontos 2008; Brysbaert, Vandenabeele and Vandenabeele 2004).

Figure 2. Black and White

However, mud plaster has been largely neglected within this discussion due to taphonomic bias, as it is often the first wall component that erodes and deteriorates, easily detaching from the wall surface. Once fallen and mixed with the room soil deposits, mud plaster is not easily recognizable, since - like most earthen building materials- it decays and blends with the soil infills. When mud plaster undergoes a conflagration and is essentially transformed into a roughly baked ceramic building material (CBM), or is preserved through specific climate conditions, it is often possible to identify it through qualitative stereoscopic analysis in the field. Even so, mud plaster studies have barely scratched the macro- and micro-features of this material, especially in relation to its use in conjunction with lime technology, or even its own independent functionality (Caron and Lynch 1988; Tsai and Hary 2016).

Architecturally, the plastering consists of multiple superimposed layers; the coarse layers of mud plaster are applied directly to the wall to smooth the external surface, followed by finer layers of clayish plaster that may constitute the finish of the external façade. In many cases, however, lime plaster is applied on top as a final fine layer to seal the wall, and often even the ceiling (Fig. 3) (Shaw 2009, 150-153; Wright 2005, 93-94, 159-160). Numerous lime plaster fragments have been recovered from both the Monastiraki and Knossos-Anetaki excavations alongside mud plaster, documenting the use of the two techniques in conjunction with each other. The qualitative study and stereoscopic analysis are the initial steps to complete a more comprehensive research on the relationship between ancient technology and architecture.

Mud and lime plaster have clearly different technological functions, as mud plaster functions to coat and protect the walls, while lime plaster works as weatherproofing and as a wall finish. Lime plaster is actually produced by heating calcareous rock (e.g. limestone) to temperatures ranging from 750 °C to 900 °C , in a process called calcinating. After heating, calcite (CaCO3) breaks down into quicklime (CaO), which then reacts with water, producing hydrated lime (Ca(OH)2), and releasing heat at the same time. When this primary product is left exposed, the carbon oxide present in the atmosphere reacts with the hydrated lime to produce calcium carbonate (CaCO3), thus forming lime plaster (Boness, Panagiotopoulos and Goren 2017, 393-394; Toffolo et al. 2017, 353-354; Wright 2005, 146). In the Minoan period, when this cycle was completed pigments were then applied, whether for fresco or secco techniques, to paint the wall (Boness; Panagiotopoulos and Goren 2017, 394; Westlake et al. 2012). This contribution presents prelimiary observations regarding the qualitative analysis of mud plaster (10 samples from Monastiraki and Knossos) and lime plaster samples (10 samples from Monastiraki and Knossos).

2. Case Studies

The analysis of lime plaster fragments from Monastiraki and Knossos indicates the use of fibres such as hair and straw as binders, as well as binder-related lime lumps created during production. The smooth external surface of the samples also denotes the use of lime plaster as an external wall coating.

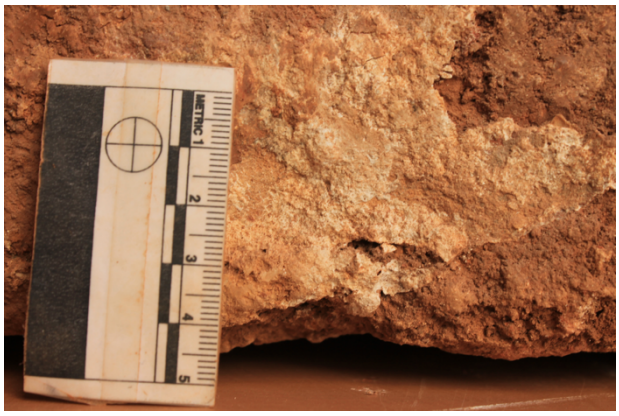

Figure 3. Color

The coarse nature of the mud plaster samples from both Monastiraki and Knossos indicates that in these cases it constituted the thick, coarse buffer layer between the actual wall and the lime plaster finish. Generally, mud plaster consists of soil, water, and vegetal temper, similar to the composition of mudbrick, but with a different proportion of ingredients and a diverse grain size ratio for its particles (Minke 2006, 40-41; Wright 2005, 93-94). The Minoan mud plaster analysed contains a

high quantity of vegetal temper consisting of straw, which is required to increase the coating flexibility and prevent shrinking (Fig.4) (Kemp 2000, 92). Architecturally, mud plaster may be used in conjunction with other forms of earthen architecture, such as mudbricks or rammed earth, but can also be employed with stone or wooden structures. In this respect, mud plaster recipes can be quite different, and often are regionalised from site-to-site based on the local raw resources. In the case studies analysed, multiple fragments have been investigated to detect any pattern of similarities or differences in plaster production between Monastiraki and Knossos-Anetaki.

Figure 4. Black and White

The stereoscopic results of the mud plaster analysis are sumarised in the table below (Table 1).

Site	Vegetal Temper	Calcite	Hematite	Mica	Quartz	Clay pellets
Knossos-Anetaki	50-60%	+++	+	++	+++	+
Monastiraki	60-70%	+	+	+	++	+++

Table 1.

Analyses conducted in the field with a stereoscopic microscope highlighted the presence of specific inclusions such as quartz, hematite, calcite, and dolomite in both the Monastiraki and Knossos-Anetaki fragments. The proportion of the inclusions clearly differs depending on the local raw sources - especially clay sources - used during manufacturing. Some of the Knossos-Anetaki fragments also present the initial popping of silica particles associated with the high temperatures reached by the materials in a conflagration.

The Monastiraki mud plaster fragments present an interesting mix of local soil and straw. Macroscopic analyses of mudbricks and mud plaster fragments from the site indicates a higher presence of vegetal temper (approx 60-70%) in the plaster as well as the presence of a lime plaster finishing layer to the external surface of the walls (Lorenzon 2017).

Although comparative analyses of Monastiraki mud plaster indicates a soil composition similar to the mudbricks present at the site, advocating for shared raw resource procurement, there is an important and clear distinction regarding the vegetal temper, on both a quantitative and qualitative level. In Monastiraki, the only temper recorded is straw, which can comprise 60-70% of the total inclusions within the mud plaster fabric (Fig.5). Mudbricks present a lower vegetal temper percentage than mud plaster, and the use of different species of plants, including seagrasses, have been recorded as vegetal temper (Lorenzon 2017). Lastly, the mud plaster fragments from the Charakas area of Monastiraki present clear evidence of conflagration such as burn marks, and are heavily intermixed with lime plaster, indicating their combined use as wall covering and possibly as part of the ceiling structure.

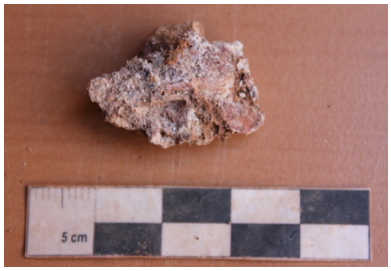

Figure 5. Black and White

Likewise, the mud plaster fragments from Knossos-Anetaki also present a quite homogenous composition with a high percentage of vegetal temper (approximately 50-60%), and the use of Knossos' distinctive pinkish clay as part of the soil mix. All of the mud plaster samples analysed from Knossos-Anetaki show signs of conflagration, with the fire affecting both their composition and eventually their structural integrity.

Specifically, the fire impacted the silica, initiating a vitrification process within the mud plaster, which contributes to its deterioration and the successive collapse. Archaeologically, the conflagration favours the study of earthen buildng material such as mud plaster, as the burning of clay and vegetal temper preserves the fragments creates a photographic negative, in which the missing components, such as vegetal temper, are visible and recognizable by their impressions. Therefore, the numerous impressions of vegetal temper attest to the high percentage of straw within Knossos mud plaster, and the use of grog alongside chaff as preferred tempering agents (Fig.6).

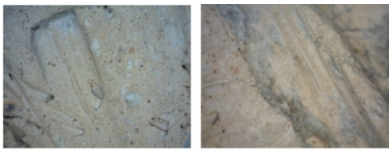

Figure 6. Black and White

The Knossos-Anetaki excavation also recovered numerous pieces of lime and mud plaster, indicating their use in the walls' finish, but also in paving and ceiling structures. Mud plaster especially may have been used as a plastic CBM (ceramic building material), as documented within the kiln structure discovered at the site. In this latter case, mud plaster was employed in conjunction with lime plaster as the main building material of the upper part of the kiln. The high straw percentage (60%) within the mud plaster strenghtens its refractory property and makes it an ideal building material for kilns (Duistermaat 2007: Appendix C; Murphy and Poblome 2016).
A relevant quantity of architectural fragments from this context shows an intermingling of lime and mud plaster, indicating that these two techniques were used in conjunction with each other as attested in other Minoan sites (Jones 2005: 208). One possible hypothesis argues that after the collapse of the structures - likely due to fire- the combination of plaster debris, heat and/or water, may have re-started the cycle of calcination, binding the mud and lime plaster together in the collapse (Evely 1993, 208; Shaw 2009, 155) (Fig.7).

Figure 7. Black and White

A few of the examples of mud plaster from Knossos-Anetaki show traces of fingerprint and wooden impressions, demonstrating that mud plaster was used as plastic material and integrated as part of the walls and ceilings when still wet and malleable (similar patterns are observed in Brysbaert 2008) (Fig.8). The analysis of the matrix of these fragments suggests their use as a coarse coating, while the presence of fingerprints indicates that this coating was not plastered with any tool, but only by hand, while successive finer coatings may have been smoothed by a tool, such as a wet rag, as evidenced by the impressions left on the surface.

Figure 8. Black and White

3. Observations

The investigation of the mud and lime plaster fragments from Monastiraki and Knossos-Anetaki allows us to draw some preliminary observations:

- mud plaster fragments present mainly straw as vegetal temper, which seems to be a constant from the Protopalatial to Neopalatial period, and is employed functionally to prevent cracking and shrinking;
- the use of natural fibers in both lime and mud plaster is documented alongside vegetal temper;
- the use of lime plaster technology is tightly interconnected with mud plaster, thus requiring an organic analysis of both materials (Shaw 2009, 141-155; Wright 2005, 163);
- lime plaster has vapour-permeable properties allowing the passage of water and humidity, and thus increasing wall preservation. This is particularly relevant when lime plaster is used in conjunction with mud plaster, as the humidity level can be one of the major issue in degradation in earthen building materials (Isebaert et al. 2016; Ravi, Rajesh, and Thirumalini 2018; Silva, Ferrera Pinto and Gomes 2016);
- fire technology, which is a key component of lime technology, does not directly affect mud plaster, but it is an important element in understanding the postdepositional process, as the collapse of the structures after a fire may re-initiates the lime cycle, binding the mud and lime plasters together.

Finally, the combination of the two types of plasters in the Minoan period, as well as the use of mud plaster in a variety of contexts, may indicate that mud plaster production was closely aligned to that of lime plaster as well as traditional mudbrick production, especially as the two processes (mud and lime plastering) required coordination and organic development within the architectural *chaîne opératoire*. Preliminary observations also seem to indicate a general homogenity of mud plaster technique in the Minoan period between regionally and typologically distinct centres, with clear

alterations based on raw resource procurement. Future research on the material should concentrate on extending the geographical and chronological focus to better understand the *chaîne opératoire* behind mud and lime plaster in the Aegean, with regards to the additives used and the specialised role of plastering within the architectural building cycle.

Acknowledgements

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FIGURE CAPTIONS

Figure 1: Monastiraki map (after Spyridakis Michalis, image courtesy of A. Kanta).
Figure 2. Knossos-Anetaki partial ground map (Image courtesy of A. Kanta).

Figure 3. Monastiraki mudbrick with mud and lime plaster fragments still attached (Photo by the author).

Figure 4. Mud plaster with vegetal impessions, Knossos-Anetaki (Photo by the author).

Figure 5. Monastiraki mud plaster fragment (Photo by the author).

Figure 6. Knossos-Anetaki mud plaster fragment with vegetal impressions (Photo by the author).

Figure 7. Mud and lime plaster intermingled (Photo by the author).

Figure 8. Fingerprint impressions on mud plaster fom Knossos-Anetaki (Photo by the author).

TABLE CAPTION

Table 1. Mud plaster composition